CANDU FUEL CHANNEL INSPECTION

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AECL – Reactor Services

Meeting with the USNRC and CNSC

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AECL TECHNOLOGIES INC.

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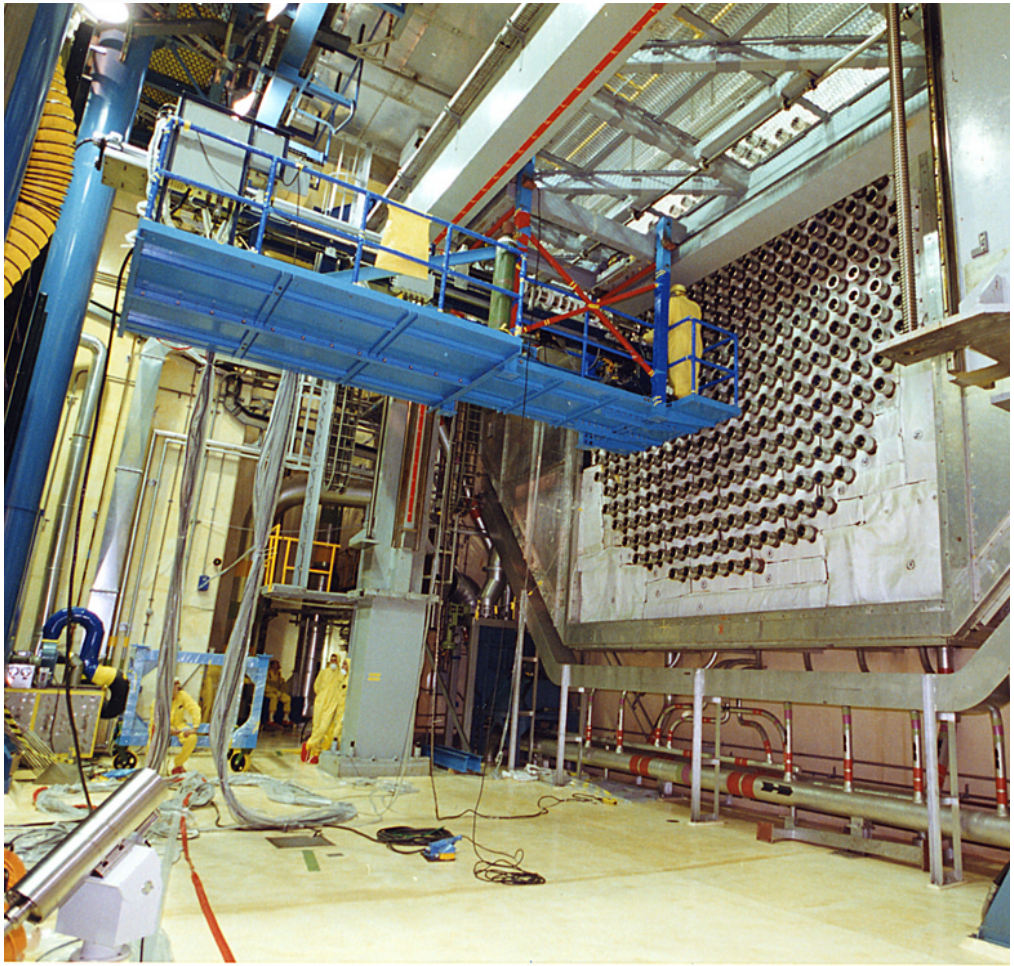


Outline

Manufacturing Inspection

- Requirements
- Inspection

In-service Inspection

- Requirements
- Inspection Equipment
- Typical Results

Manufacturing Inspection Requirements

Inspection Criteria:	CAN/CSA-N285.6.6
Pressure Tubes:	CAN/CSA-N285.6.1
Calandria Tubes:	CAN/CSA-N285.6.4
Garter Spring Wire:	CAN/CSA-N285.6.5
End-Fittings:	CAN/CSA-N285.6.8

Pressure Tube Manufacturing Inspection

Ingot:

- Ultrasonic normal beam (ASTM B350)

Billet:

- Circumferential ultrasonic shear wave in 2 directions
- Ultrasonic normal beam

Pressure Tube:

- Hydrostatic test after cold drawing
- Five-direction UT after final grinding/honing
- Five-direction UT after stress relief and straightening
- ET on ID and OD
- Wall thickness
- Diameter

PT Volumetric Inspection Calibration References

Manufacturing:

- **Ingot:** 1/16 inch dia. side drilled holes (SDH)
- **Billet:** ¼" long x 0.030" deep notches (2)
  0.050" dia. SDH
  0.060" dia. FBH
- **Pressure Tube:**
  ¼" long x 0.003" deep notches (4)
  0.030" x 0.060" FBH (5)

In-Service:

N285.4-94

¼" long x 0.006" deep notches (4)
0.030" x 0.060" FBH (3)

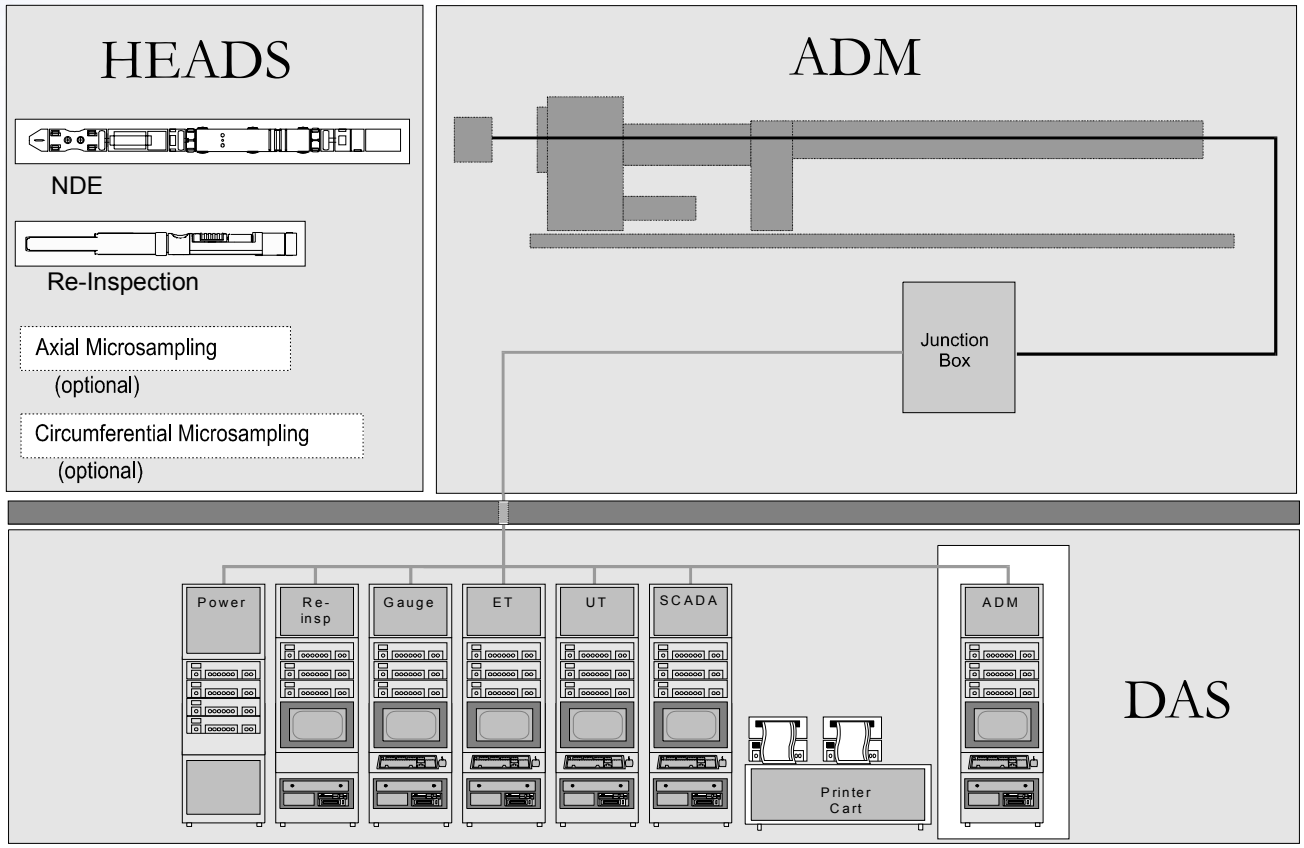
In-service Fuel Channel Inspections
CAN/CSA-N285.4

VERSION	SERVICE YEARS	NO. OF CHANNELS	
		PRE-SERVICE	IN-SERVICE
N285.4-M83	<0	14 (Inaugural)	
	1 - 5		5
	10 - 15		5
	20 - 25		5
N285.4-94	1 - 2		12
	4 - 7		5
	10 - 13		5
	16 - 22		5
	25 - 28		5

In-Service Inspection Requirements Specified in CAN/CSA-N285.4, Clause 12

- Volumetric inspection of entire pressure tube
- Pressure tube diameter
- Pressure tube wall thickness
- Garter spring location
- Channel deflection (sag)
- Pressure/calandria tube gap
- Channel position on bearings
- Hydrogen isotope concentration
- Fracture toughness and DHC velocity

AFCIS Schematic



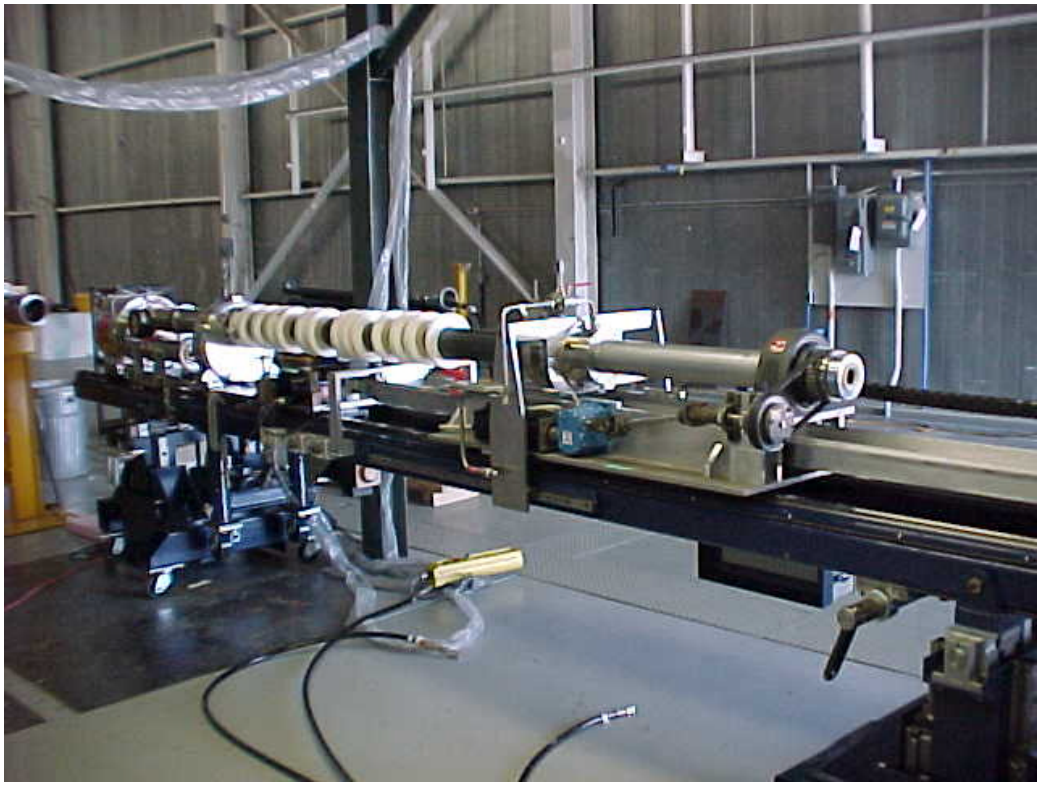
AFCIS – AECL Fuel Channel Inspection System

ADM – Advanced Delivery Machine

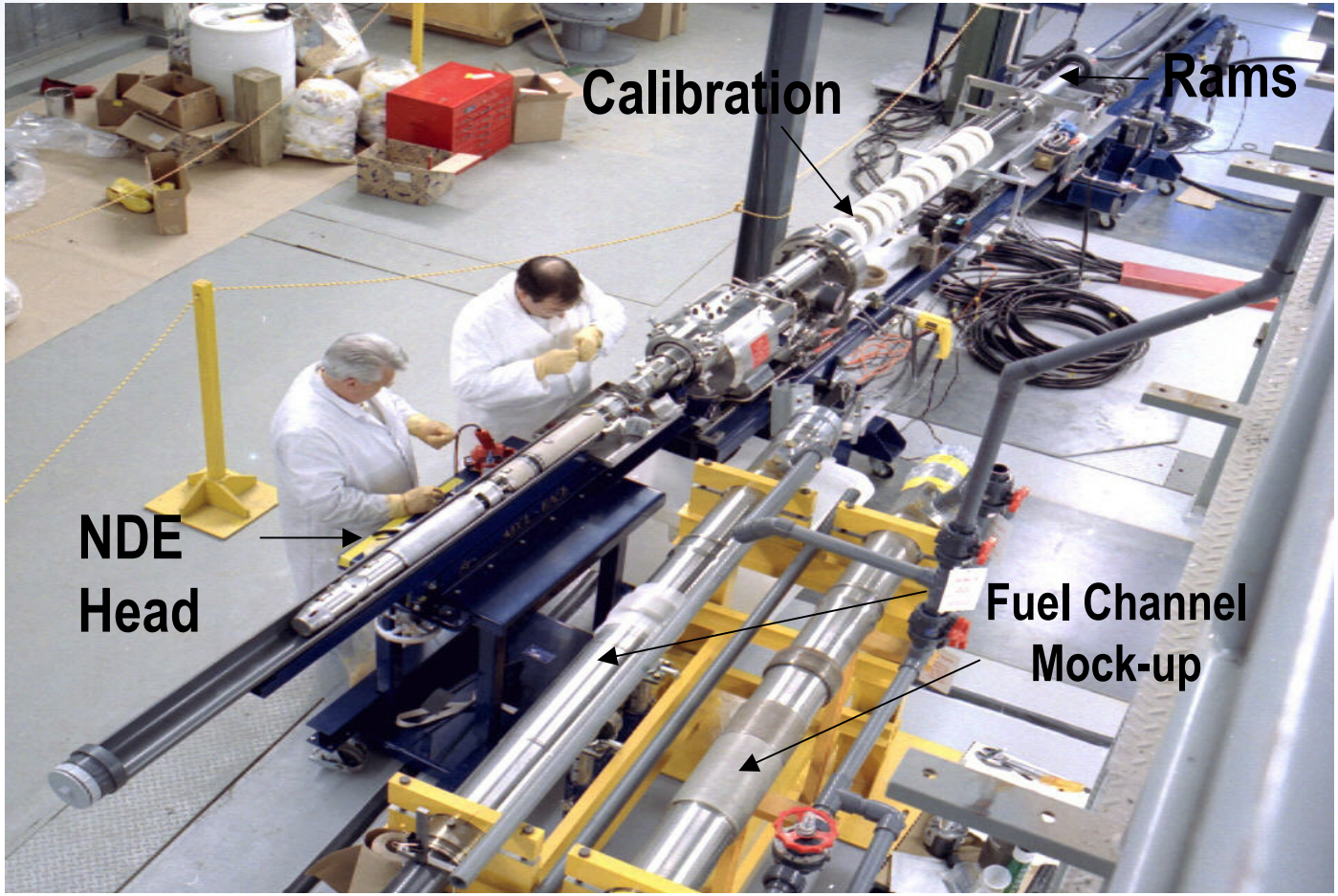
DAS – Data Acquisition System

N285.4 Requirement	Measurement Technique Used on AFCIS
Volumetric Inspection of entire pressure tube	
- Flaw detection	Ultrasonic Testing (UT), Eddy Current Testing (ET)
- Flaw characterization	UT, ET, Video, Replication
Diameter Gauging	Linear Variable Differential Transformer (LVDT)
Wall Thickness	UT
Garter Spring Location	
- Installation	ET
- In-service	UT, Gauging Data
Channel Sag	LVDT
Pressure/Calandria Tube Gap	ET (UT)
Position on Bearings	PT Length obtained from AFCIS position read-out & diameter gauging
Hydrogen Isotope Concentration	Multi-head Sampling Tool

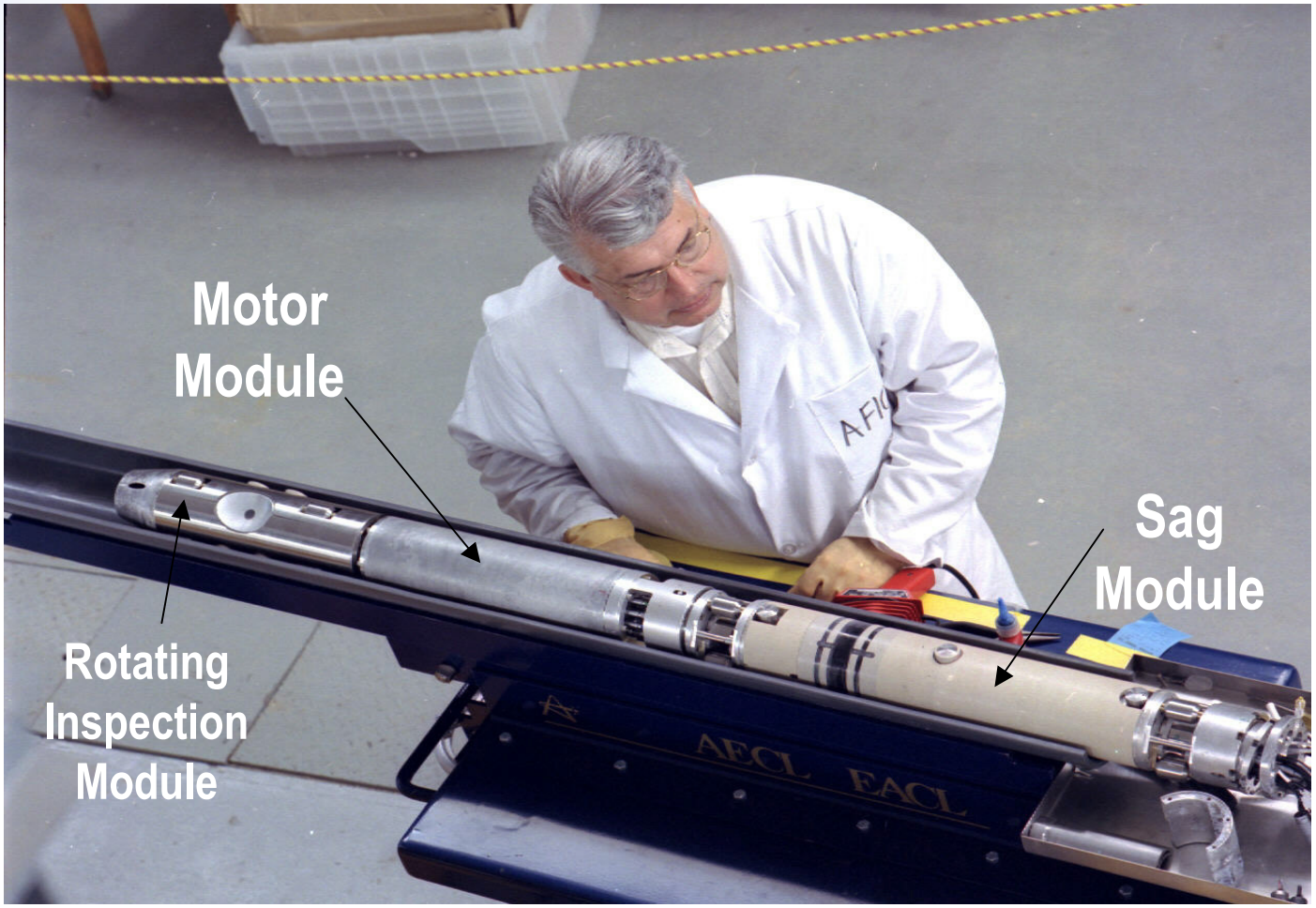
ADM Rear View



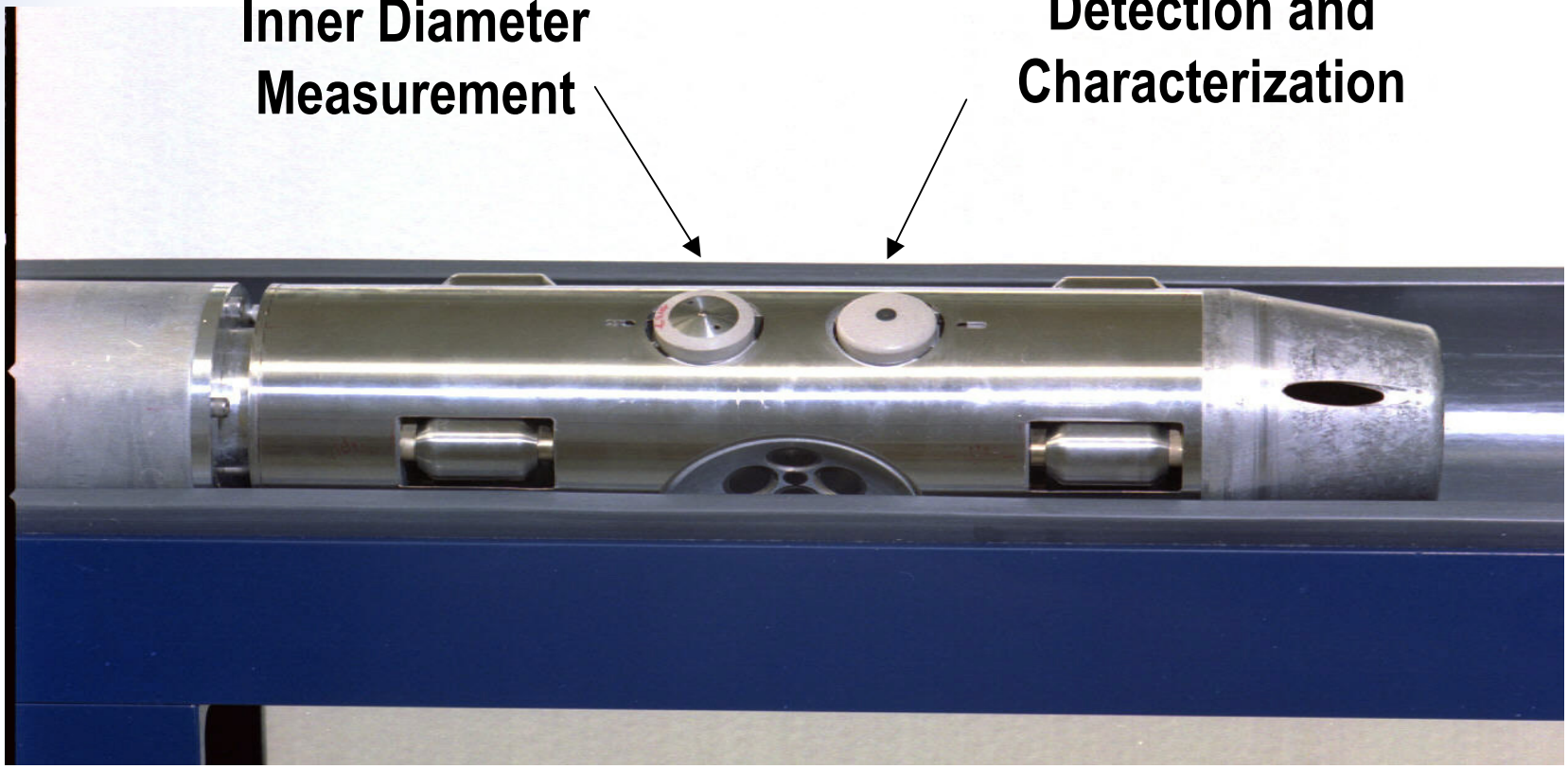
ADM – Front View with Inspection Head



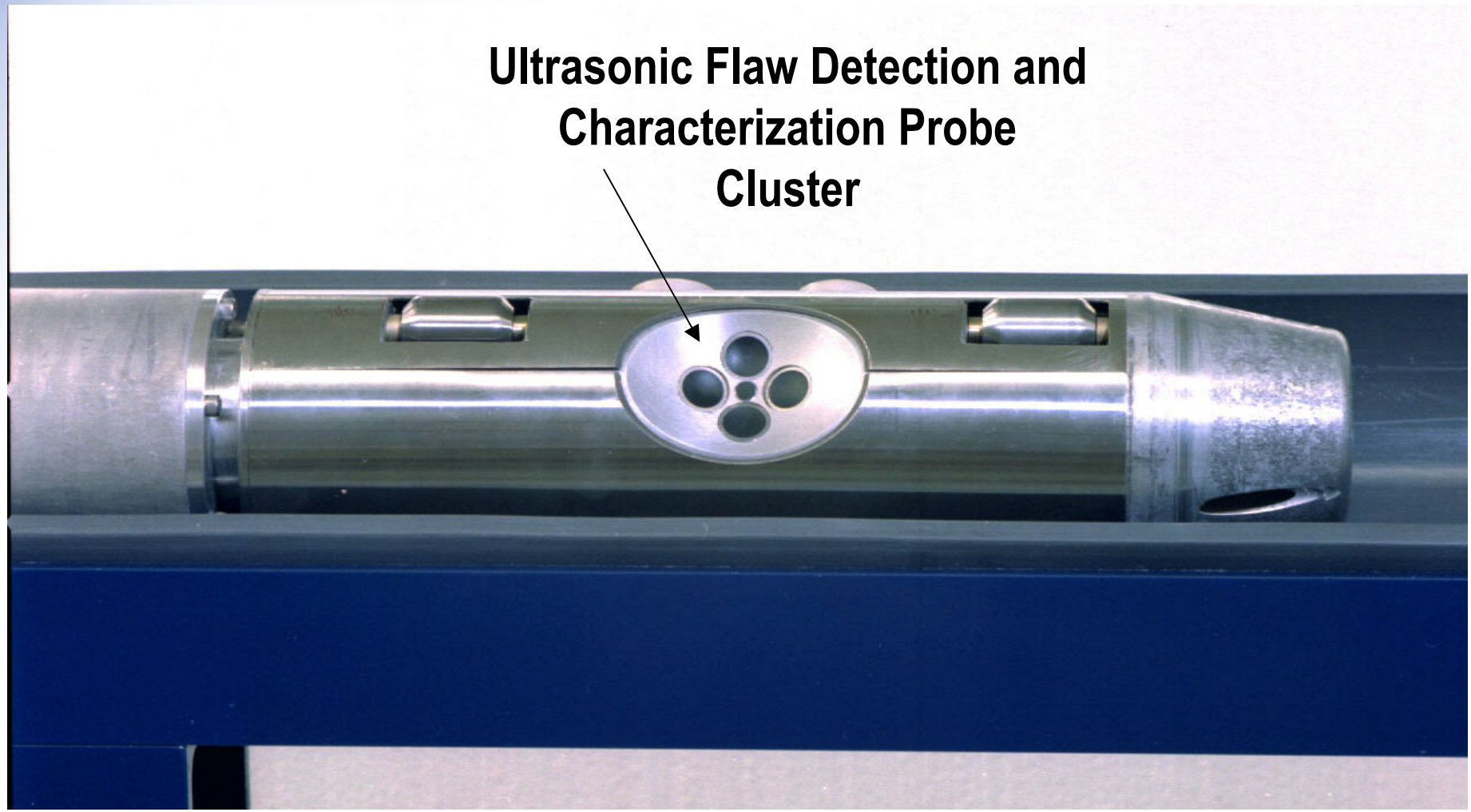
Primary Inspection Head



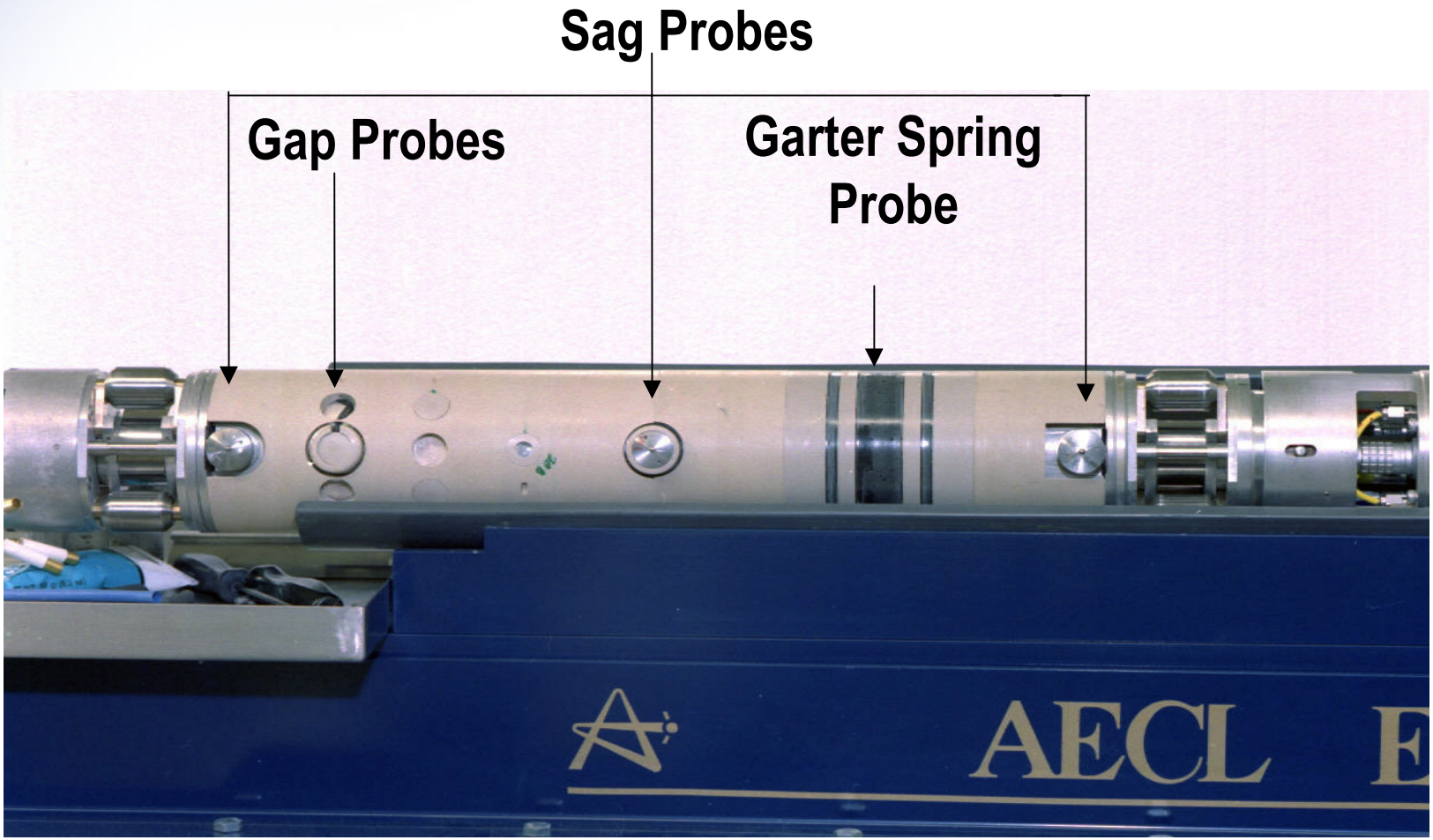
Rotating Inspection Module



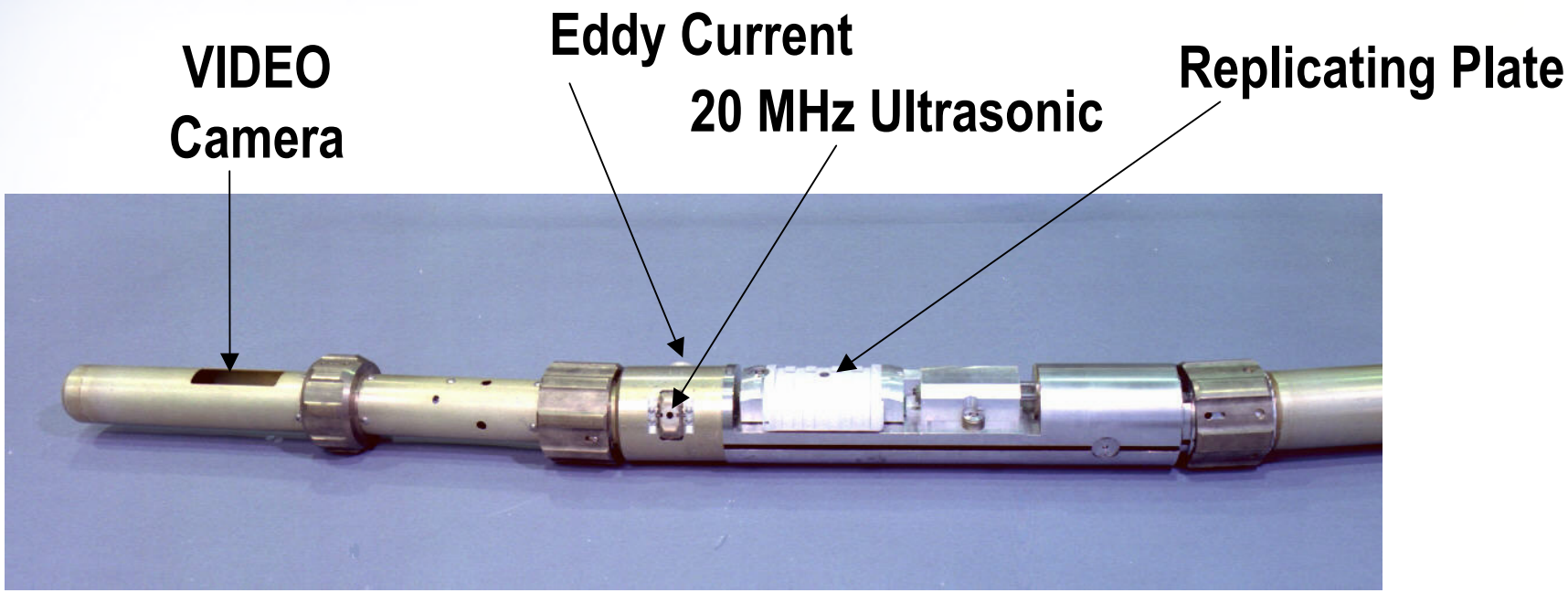
Rotating Inspection Module



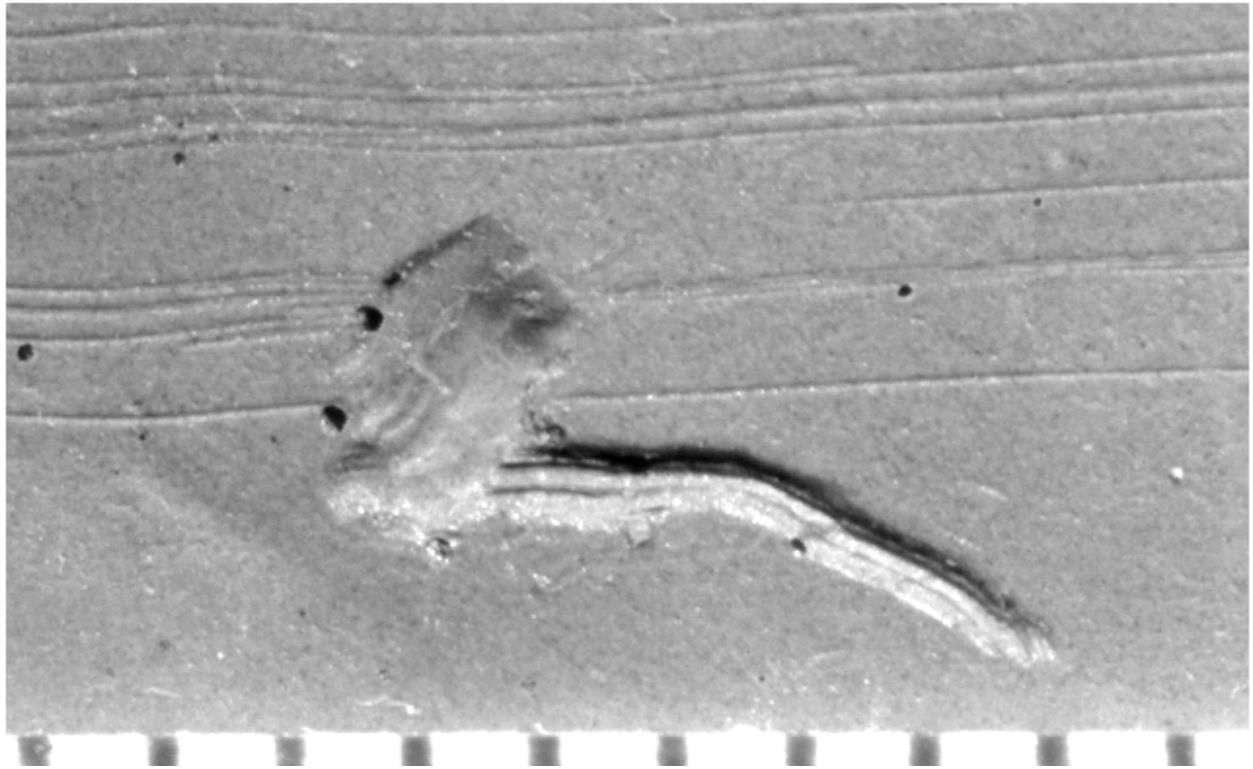
Sag Module



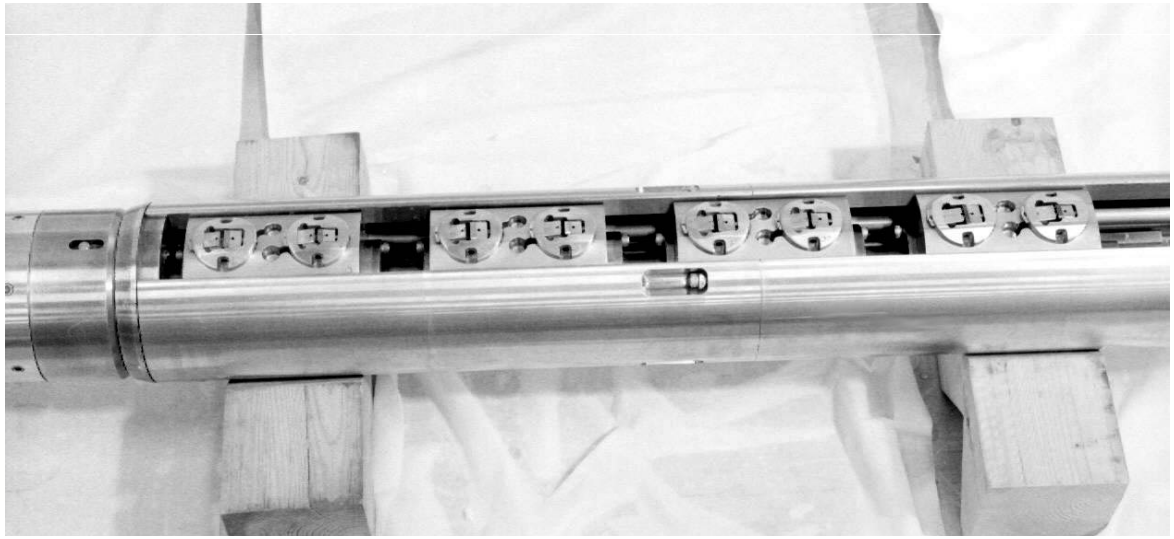
Re-inspection Head



AFCIS Replica



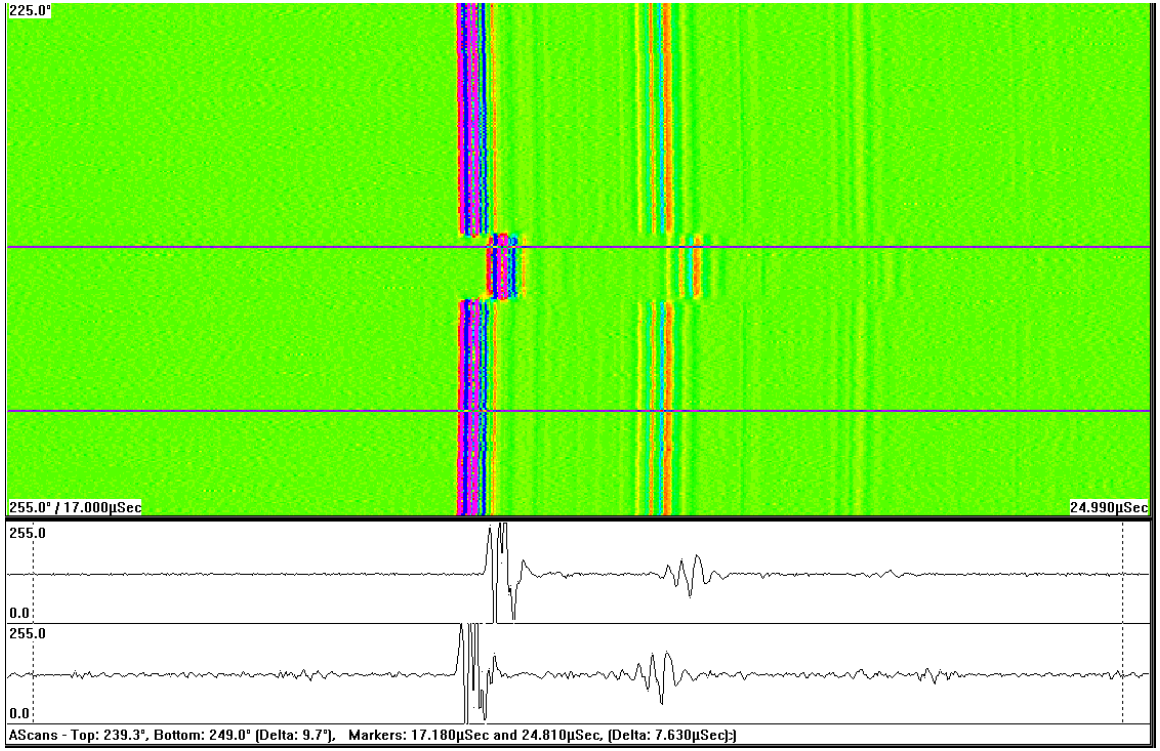
Multi-Head Sampling Tool



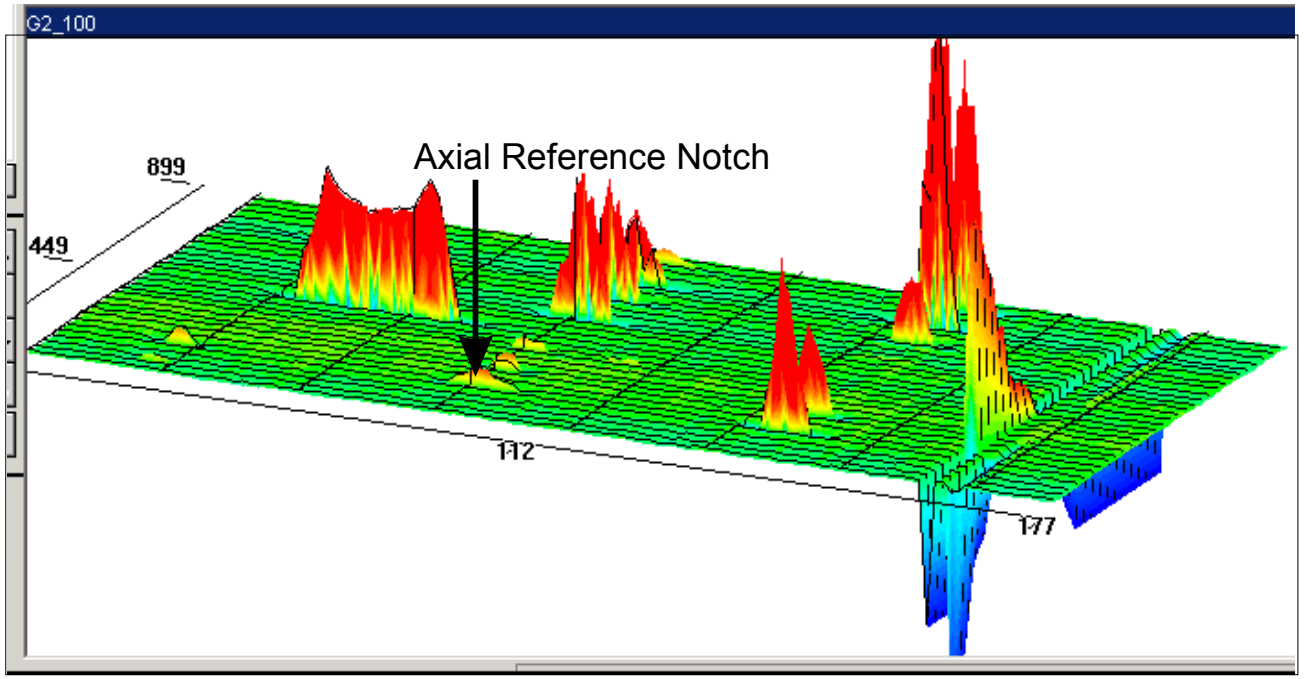
AFCIS Channel Inspection Sequence

	Length	GS	UT-V	ET-V	Dia.	WT	Axial Gap		Circ. Gap	6:00/12:00 Sag	12:00/6:00 Sag
							@6:00	@12:00			
Clamp-on ADM & remove closure											
Initial Calibrations		x	x	x	x	x					
Scan Pass #1 - Insert	X	X									
Scan Pass #1 - Retract			X	X	X	X					
Intermediate Calibrations		x	x	x	x	x	x			x	x
Scan Pass #2 - Insert							X			X	
Scan Pass #2 - Retract								X			X
Scan Pass #3 - Insert							Available - sometimes used for a 3:00 gap scan				
Scan Pass #3 - Retract									X		
Final Calibrations							x			x	x
Rescans - if required											
Install Closure & unclamp ADM											

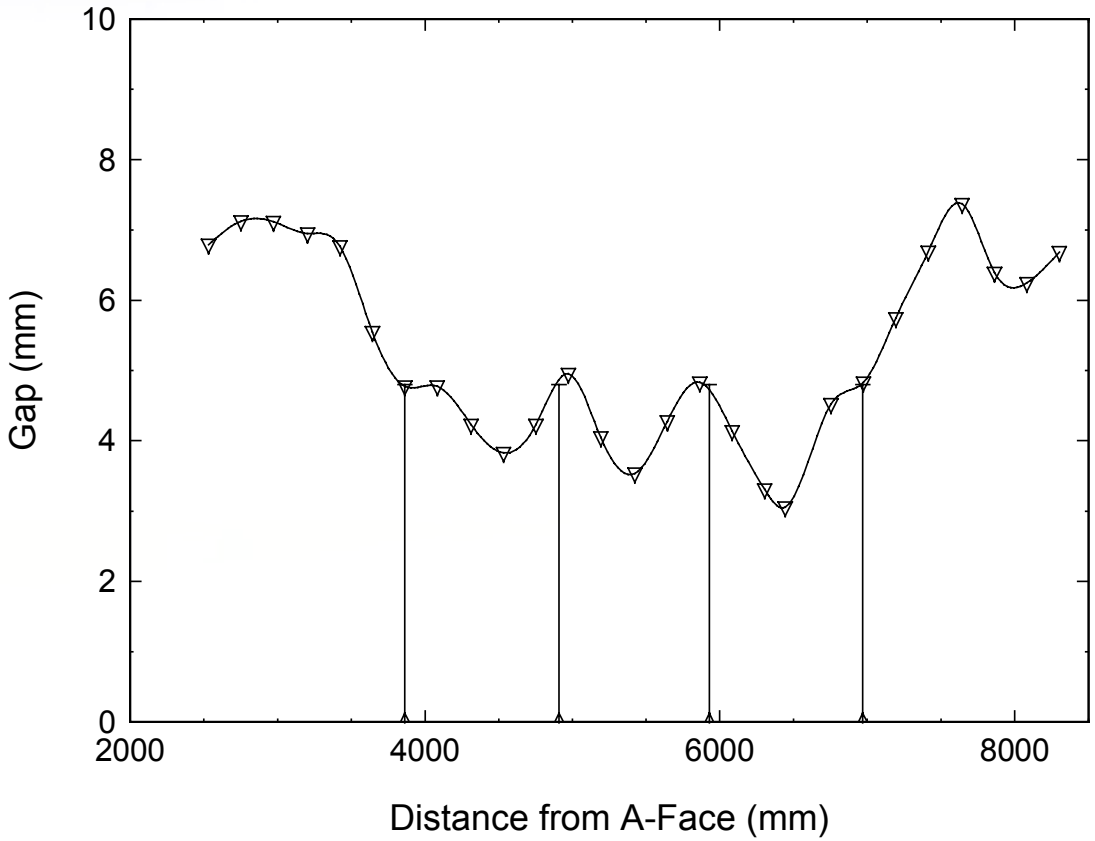
20 MHz Ultrasonic B-Scan of 0.006” Deep Notch



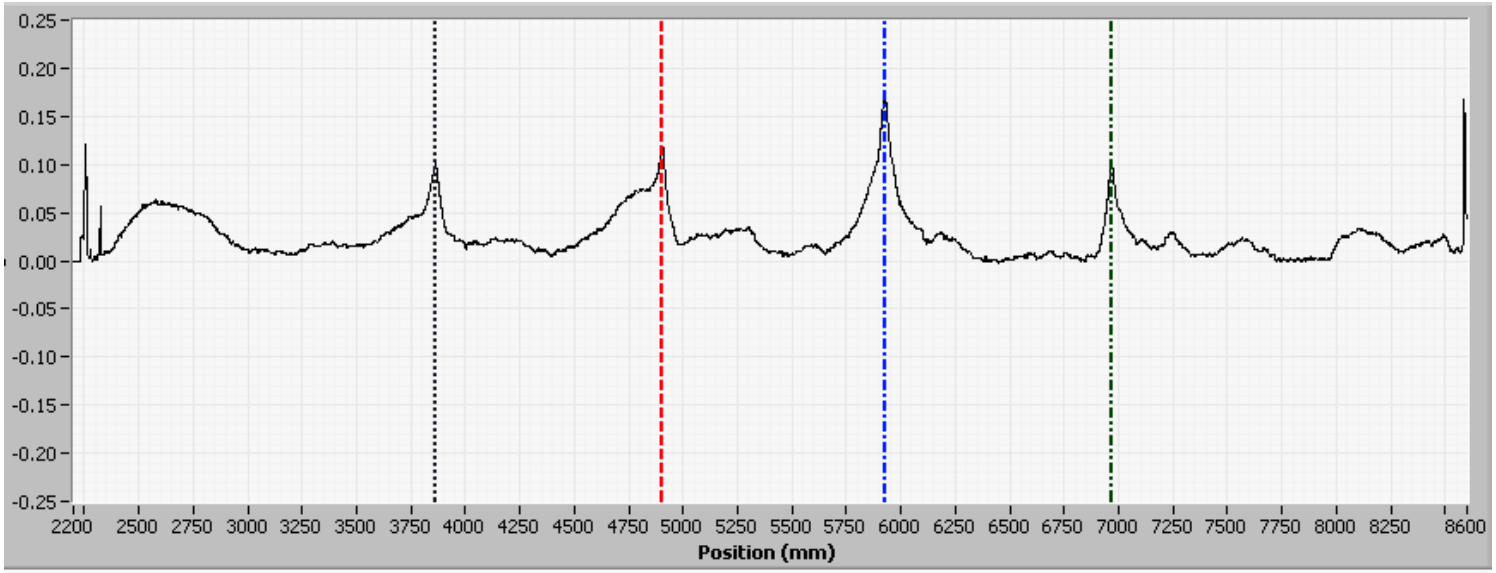
ET C-scan of AFCIS Calibration Tube



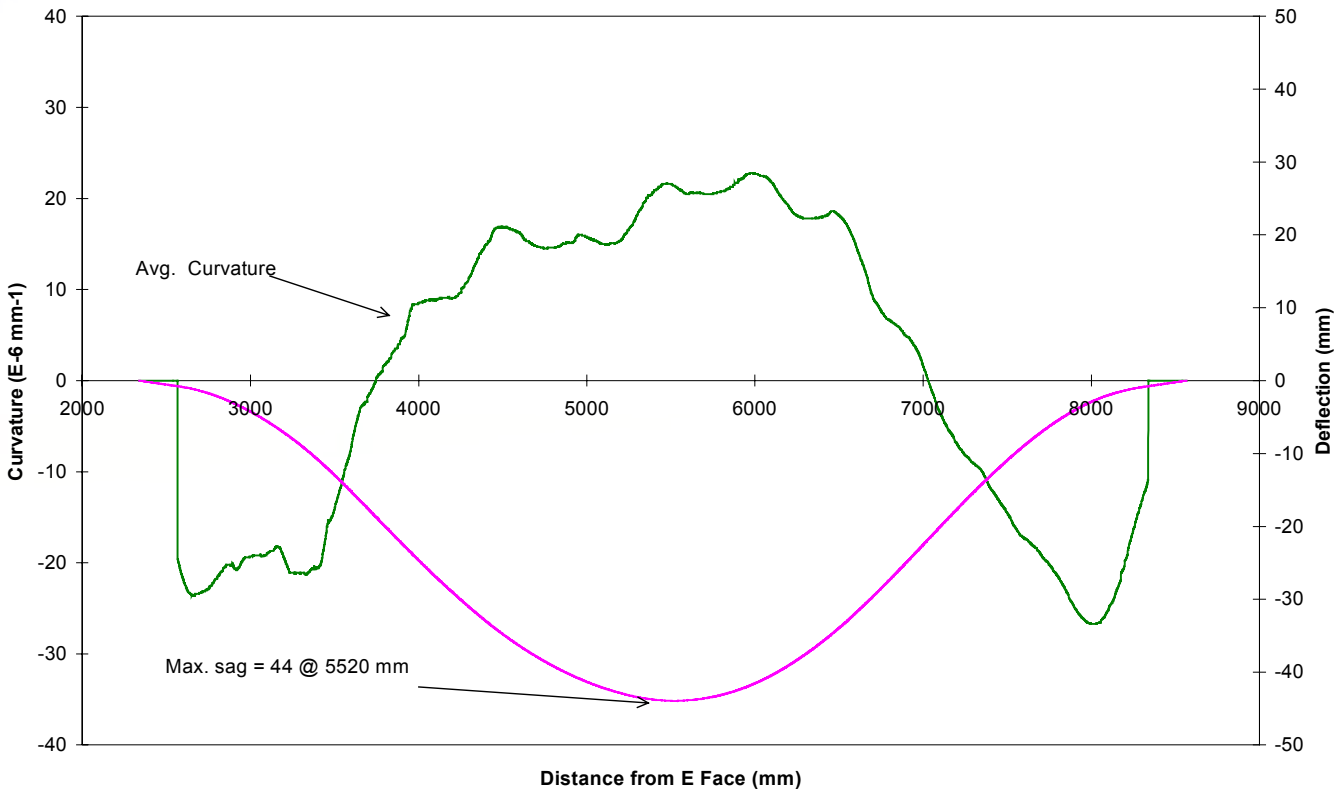
PT/CT Gap Profile



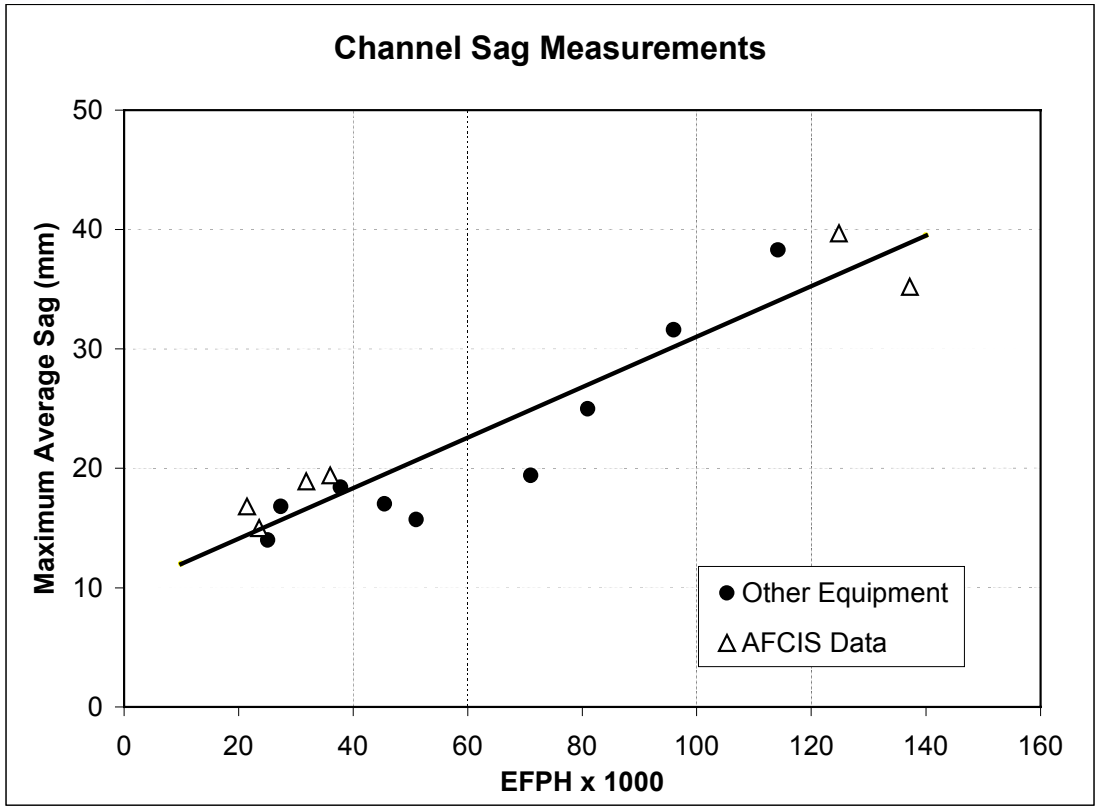
Processed Diameter Data for Snug Spacers



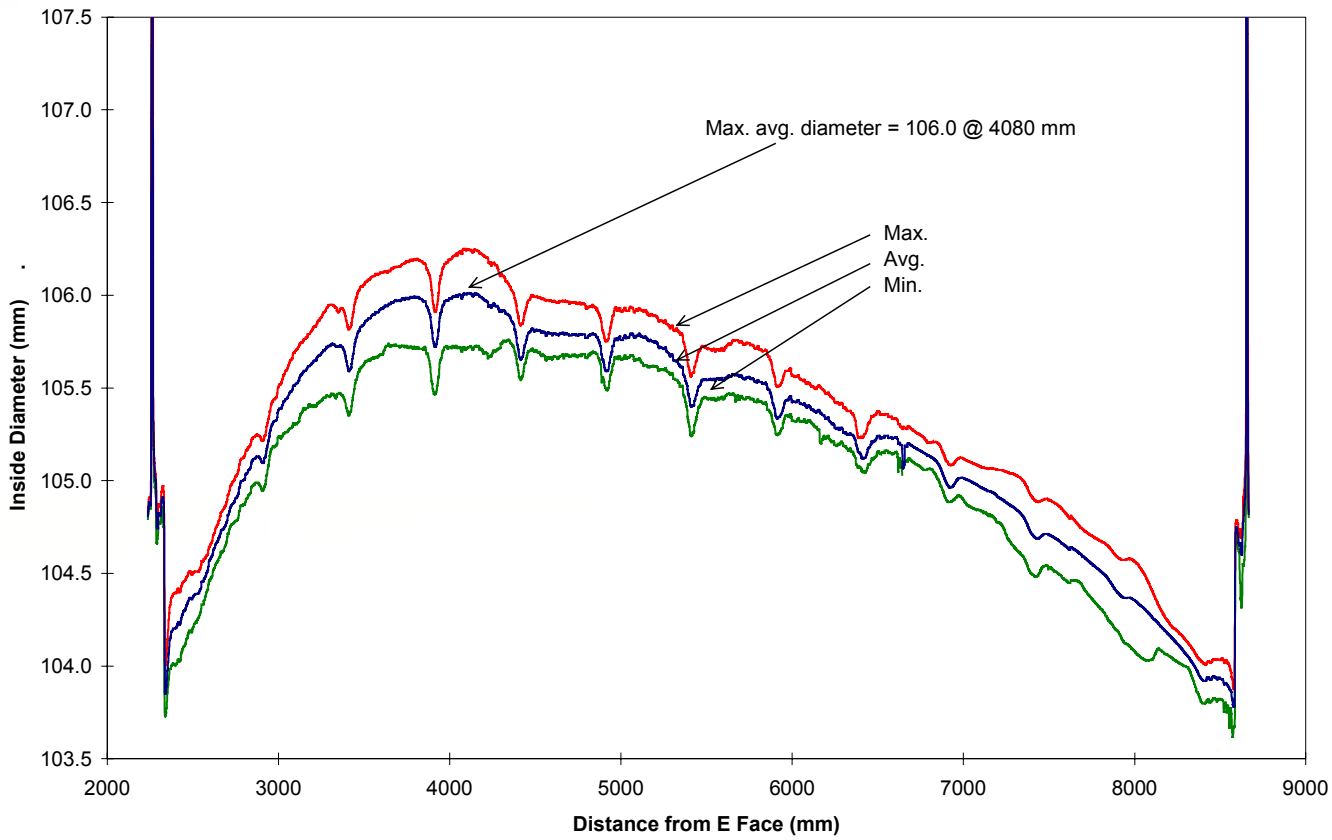
Channel Curvature & Sag Profile



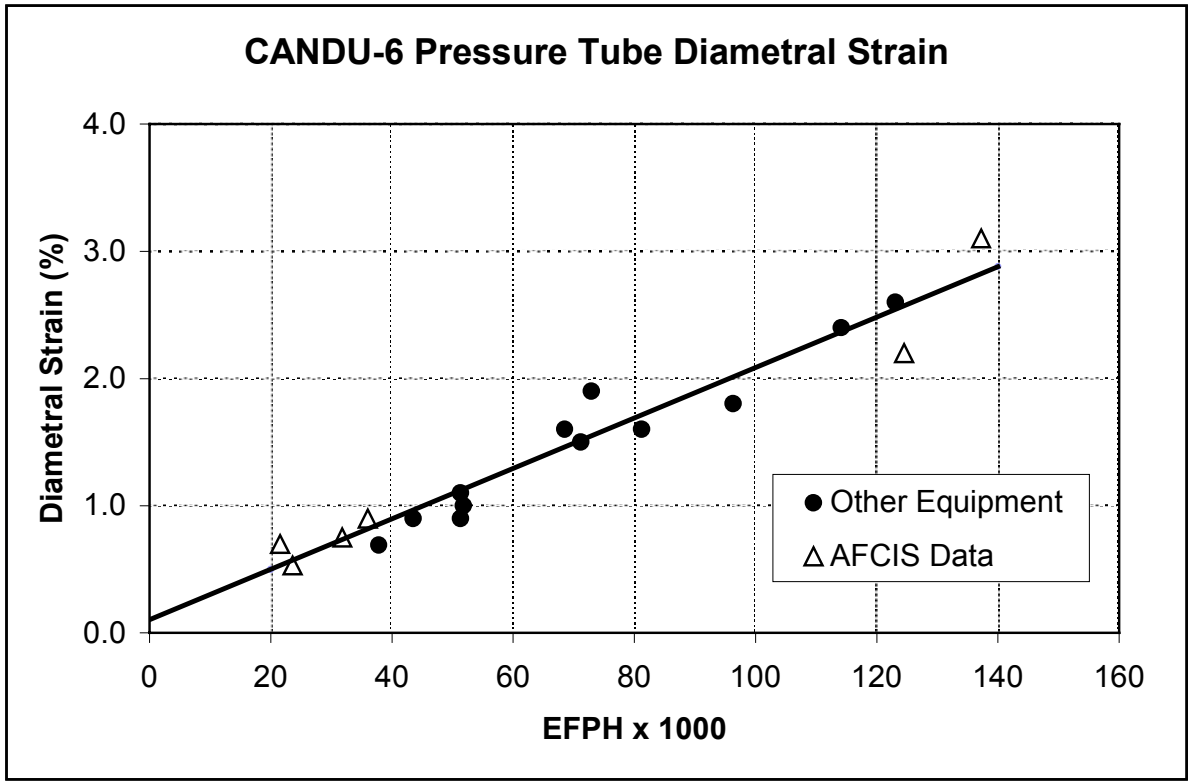
Channel Sag Measurements



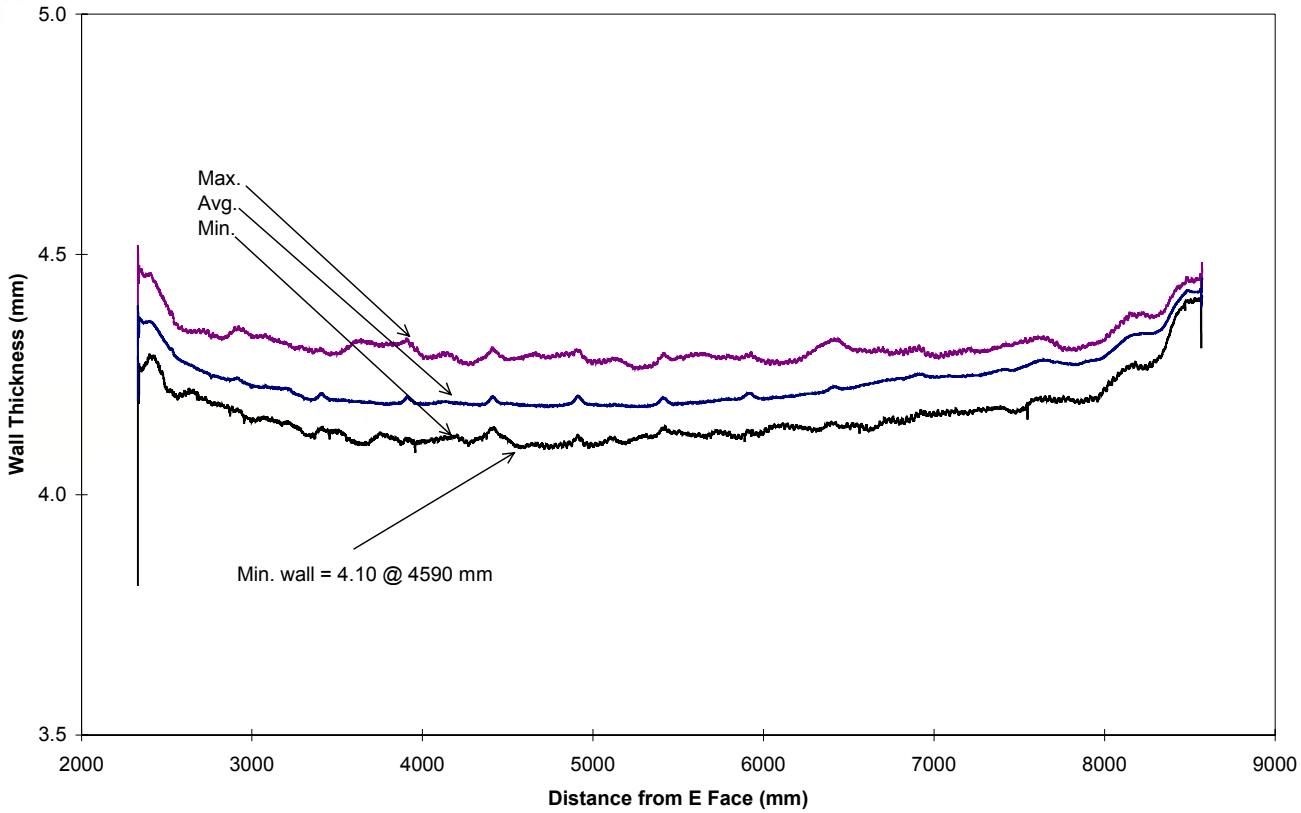
PT Diameter Profiles



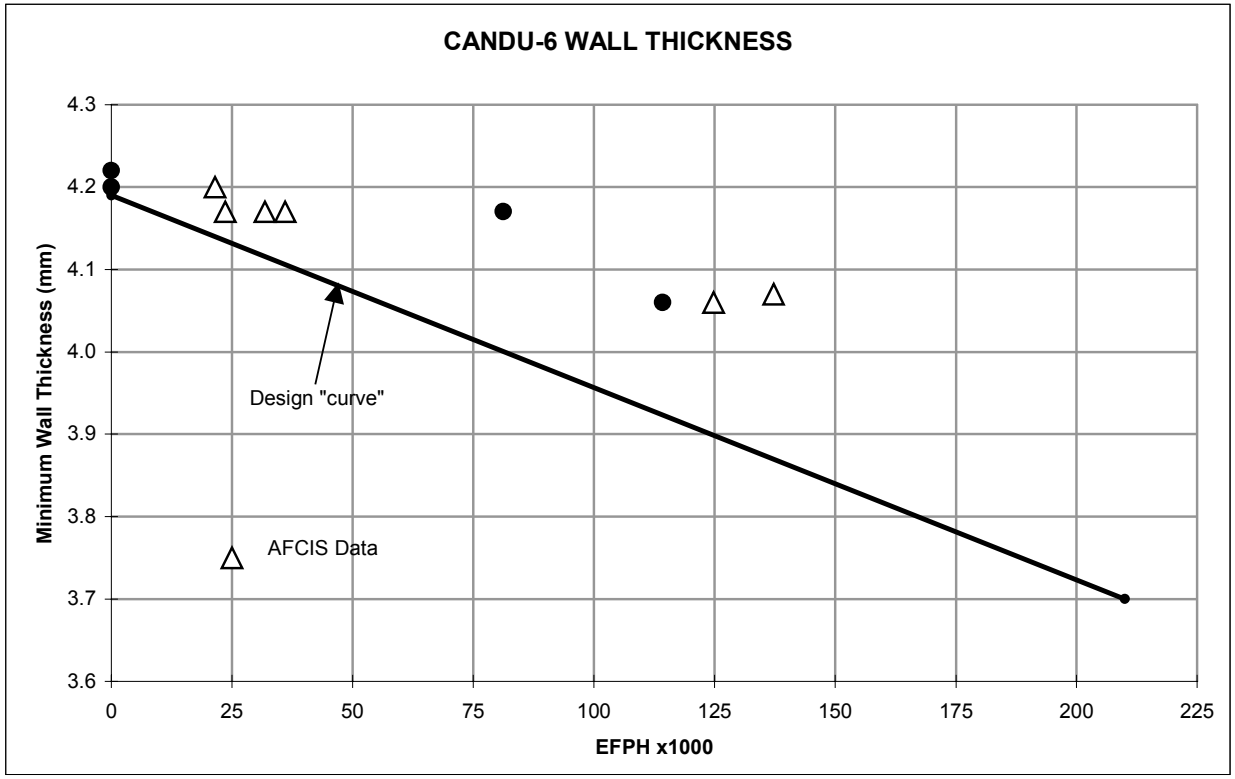
PT Diametral Growth Measurements



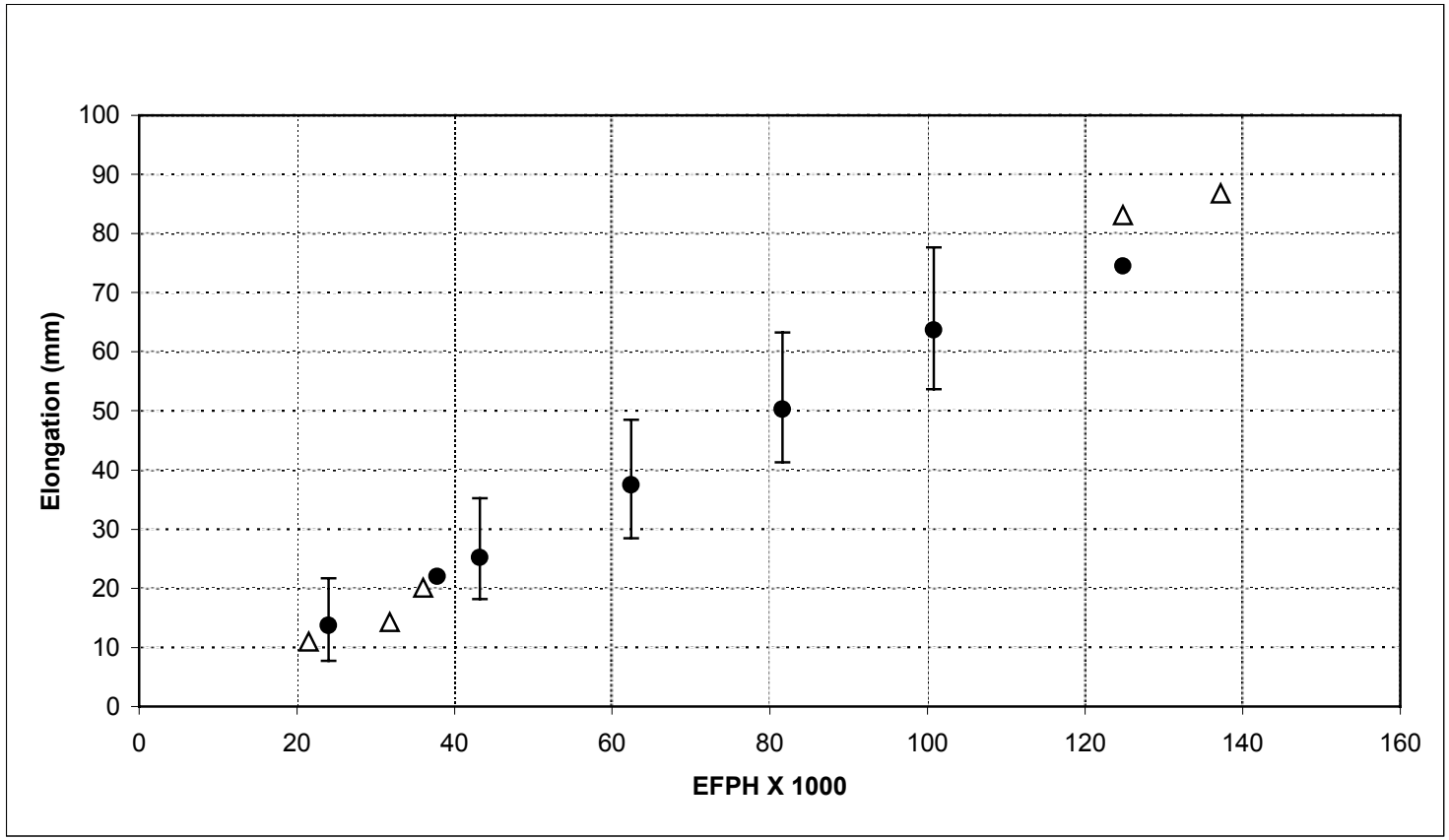
PT Wall Thickness Profiles



PT Wall Thickness Measurements



PT Length Measurements



Summary/Conclusions

- The CAN/CSA nuclear standards include comprehensive requirements for both manufacturing and in-service inspection of CANDU fuel channel components.

- Equipment, procedures and qualified staff exist that can satisfy inspection requirements.

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